Disrupting education through blockchain-based education technology?

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This study is the first to systematically analyse the use of blockchain technology in education. In particular, we analyse the status quo of blockchain-based education technologies (*N* = 62). We performed a qualitative content analysis of providers' websites to analyse the characteristics of their technologies. The analysis reveals that existing blockchain-based education technologies are diverse and offer important advantages for education (e.g., trust and equal opportunities). Employers seem to profit from these technologies (e.g., trust in applicants), but only some technologies contribute to the individualization of education. Current blockchain-based education technologies were primarily made for the general public or for job seekers. We conclude that blockchain technology might disrupt education but that this process of change is only in its infancy. Given the high relevance of this topic, we conclude by developing an agenda for future research.

1 Introduction

Because blockchain technology (a distributed and encrypted digital database) holds the potential to innovate education, both from the perspective of the digital transformation of education and from a social innovation perspective, it is critical to analyse the landscape of blockchain-based education technology (c.f., Grech & Camilleri, 2017; Iansiti & Lakhani, 2017; Tapscott & Tapscott, 2016). Changes in education enabled by blockchain technology may offer opportunities to digitalize current education and may increase the potential to disrupt education.

First, blockchain technology enables innovative opportunities in education that may induce digital transformation in education through decentralization and democratization (c.f., Kosba, Miller, Shi, Wen, & Papamanthou, 2016; Piscini, Guastella, Rozman, & Nassim, 2016; Zyskind & Nathan, 2015) and may even lead to disruption of brick-and-mortar education. Because of blockchain technology, the possibility of digitalizing educational services might become much more concrete than it has been in recent years (c.f., Chen, Xu, Lu, & Chen, 2018; Seebacher & Schüritz, 2017). Blockchain technology, frequently referred to as "the trust machine" (Tapscott & Tapscott, 2016), allows the storage of decentralized records that cannot be tampered with (Piscini et al., 2016; Swan, 2015; Zyskind & Nathan, 2015). Entries on the blockchain are permanent and accountable (Piscini et al., 2016).

These characteristics enable new opportunities in education and therefore a wide range of service innovations. For example, a variety of educational data can be stored on a blockchain. These data can range from single certificates to an individual's entire set of performance data (e.g., a certificate of a language course or a degree from a university). Due to its architecture as a digital network, blockchain technology also allows the retrieval of data (e.g., a person's educational achievements are securely stored) across all connected parties (c.f., Swan, 2015; Underwood, 2016). Because the blockchain technology makes it possible to issue and store certificates (i.e., through hashes and smart contracts), different facilities can provide education much more easily and learners can, for example, potentially earn a degree by combining courses from different facilities. Taken to the extreme, this possibility might lead to a fundamental change in the nature of universities as institutions by decoupling education from particular institutions. This decoupling of education is an example of blockchain technology's potential to cut out intermediaries (i.e., middlemen) and decentralize entire industries (Iansiti & Lakhani, 2017; Tapscott & Tapscott, 2016; Yli-Huumo, Ko, Choi, Park, & Smolander, 2016; Zyskind & Nathan, 2015). This decentralization of education technology could therefore lead to a so-called low-end disruption, meaning that blockchain technology-based education-technology providers enter the higher education market at the low end and replace universities (i.e., middlemen) (Christensen, McDonald, Altman, & Palmer, 2016).

However, these are only a few examples, and the possibilities for changing education through blockchain technology are manifold. For example, tokens can be used to motivate learners (Chen et al., 2018). A particular example is the platform Tutellus, which uses blockchain technology as a basis for tokens that users can earn through participation in the platform. Relatedly, there are also advantages for employers, who can place more trust in the legitimacy of the educational achievements of applicants. For example, the blockchain-based technology Apii is planning to use blockchain-technology to verify the curriculum vitae of applicants, which makes the recruitment process more transparent.

A second and closely related advantage, from a social innovation perspective, is that blockchain-based education technology can provide educational opportunities for learners in impoverished or developing countries (c.f., Underwood, 2016). Blockchain technology might therefore lead to a democratization of education. By offering the possibility of profiting from education to learners who, until now, did not have access to education, blockchain technology might enable a so-called new market disruption (Christensen et al., 2016). For example, blockchain technology allows the storage of a digital identity that can provide proof of education for learners in remote areas. In particular, finding a means by which to store educational data safely on a blockchain and being able to provide proof of education in such a way allows tremendous advantages for our society. For example, refugees' access to higher education in an entirely different country could be facilitated by storing proof of their educational achievements (e.g., university degrees, number of credits) with blockchain technology.

Previous research has established the vast innovative potential of blockchain-based technologies. For example, blockchain technology enabled new opportunities in the finance industry (e.g., cryptocurrencies or money transfer) (Friedlmaier, Tumasjan, & Welpe, 2017). In their review of the different technological areas to which blockchain is relevant, Yli-Huumo et al. (2016) found that only 20 % of the papers under investigation addressed blockchain-related issues other than cryptocurrencies. Further research reflects the current landscape of blockchain-based firms: Friedlmaier et al. (2017) analysed the entire landscape of blockchain-based firms and found that 42 % of the firms operated in the finance and insurance industry and 36.5 % in the information and communication industry. However, only 0.5 % of the firms operated in the education technology industry. Thus, it is not surprising that research on blockchain in the education technology industry is rather scarce. This scarcity is demonstrated in a recent review on blockchain-related research, which mentions the application of blockchain to education only briefly in the section titled "others" (Sharples & Domingue, 2016).

In the education technology context, Sharples and Domingue (2016) suggest that the academic community should use blockchain technology as a reward system and as a "permanent distributed record" (p.1) of intellectual accomplishments. Grech and Camilleri (2017) use case studies and unsystematic interviews to assess the potential of blockchain for learners. They assume that in the field of education, blockchain technology will disrupt the *"award of qualifications, licensing and accreditation, management of student records, intellectual property management* (see Sharples & Domingue, 2016) *and payments"* (p. 10). The authors further assume that the biggest advantages of blockchain technology for education are self-sovereignty, trust, immutability, disintermediation and collaboration. Similarly, Chen et al. (2018) explored potential applications of blockchain technology in education and concluded that this technology can be used for performance assessments and results in a decrease in information asymmetry, an increase in trust between educator and learner, and more authenticity.

Despite the merits of these few articles that focus on the education technology context, systematic empirical research on blockchain technology in education is thus far absent. In particular, we need an overview of the possibilities currently offered by blockchain-based education technology as well as an understanding of their characteristics to reveal their advantages. Through this analysis of the status quo of blockchain-based education technology, one can draw conclusions on the disruptive potential (i.e., which changes they might induce) of these technologies. This approach is particularly good, as disruption can hardly be predicted before it has occurred, and this paper therefore concentrates on the potential of blockchain-based technologies to induce change in education. This paper uses previous research (e.g., Chen et al., 2018; Grech & Camilleri, 2017) as a starting point and systematically analyses the blockchain-based education technologies that are available today and that will be released soon. We characterize blockchain-based education technology according to the following characteristics: the particular role the blockchain technology plays in education technologies; the functionality of those technologies (i.e., which aspect of education they might disrupt); and the advantages the blockchain-based education technology might provide for learners and potential employers. Moreover, we analyse the target group for which the technology is built (e.g., higher education). In sum, we assess the status quo of blockchain-based education technologies, which serves as a foundation for our research agenda for blockchain-based education technologies.

Our results allow us to determine whether the currently available blockchain-based education technologies qualify as facilitators of current brick-and-mortar education or as entirely new service innovations (c.f., Iansiti & Lakhani, 2017). From a practical point of view, our results address recent calls in the literature to raise awareness among educational stakeholders of the possibilities offered through blockchain-based education technologies (Chen et al., 2018; Grech & Camilleri, 2017).

This paper is organized as follows. We begin with a short introduction to the meaning of blockchain technology and its characteristics that are relevant to education technology. Subsequently, we explain our research method (i.e., a systematic assessment of venture databases performed to generate a conclusive sample of blockchain-based education technology applications, followed by a content analysis to retrieve information about the technologies). Finally, we present the results of our research and conclude with a discussion focusing on the meaning of blockchain technology for education and an agenda for future research.

2 Blockchain technology and its use in education

2.1 Blockchain technology

Blockchain technology was initially programmed for Bitcoin (i.e., a cryptocurrency). There are now various additional versions and applications of blockchain technology, such as Ethereum (Wood, 2014). This paper focuses on blockchain technology in general.

Attempting to understand the advantages of blockchain technology for education – compared to conventional ways of handling educational data – requires an understanding of the basic principles of blockchain technology. First, blockchain technology represents a distributed database (i. e., repository or ledger), which implies that blockchain technology is based on a peer-to-peer network (Iansiti & Lakhani, 2017; Zambrano, Seward, & Sayo, 2017). The database is shared with each party connected to the blockchain (i. e., a person with a computer connected to the blockchain). Each of these parties represents one node in the network (Cachin, 2016). Second, blockchain technology is based on consensus (i. e., using cryptographic algorithms; Kosba et al., 2016; Underwood, 2016), which signifies that each new record is verified through consensus algorithms (e. g., a proof-of-work algorithm in case of the Bitcoin blockchain). Each record has a digital signature so that it can be traced back to its source. Subsequently, the records are stored in a block of data and distributed to each node (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016; Swan, 2015). Each added block of data represents a new block in the chain (i. e., the blocks are interlinked) (Underwood, 2016). The blockchain grows as more blocks are added and the blocks are interlinked through identifiers (Zambrano et al., 2017). The blockchain is therefore a decentralized network (Kosba et al., 2016; Zyskind & Nathan, 2015). Because of this decentralization of the records stored on the blockchain, the data are much harder to change than is the case when transactions are centrally stored with only one institution (e. g., a bank in case of money transferring; Friedlmaier et al., 2017; Iansiti & Lakhani, 2017; Piscini et al., 2016).

The main use of blockchain technology is to create trust between the involved entities (Mainelli & Smith, 2015; Underwood, 2016). In particular, because its records are very securely stored as well as traceable and linked to their origins, and because of the possibility to ensure the legitimacy of transactions between parties, blockchain technology allows the elimination of intermediaries. Such intermediaries might be banks in a bank transfer, lawyers in contracts (i. e., smart contracts) or, as in the context of this paper, educational institutions in learning (Iansiti & Lakhani, 2017; Yli-Huumo et al., 2016; Zyskind & Nathan, 2015). Without blockchain technology, these intermediaries need to ensure that transactions or contracts are trustworthy (Mainelli & Smith, 2015).

2.2 Characteristics of blockchain technology in the context of education technology

Different types of information can be stored using blockchain technology (i. e., records). Important forms of records are asset transactions (e. g., transactions of currency, to pay for education or tokens for successful learners; Crosby et al., 2016; Nakamoto, 2008), smart contracts (Cong & He, 2018; Kosba et al., 2016) and digital certificates or signatures (i. e., usually hashes referring to the certificate, e. g., educational certificates; Grech & Camilleri, 2017; Peters & Panayi, 2016). A particular form of such certificates that is important for education is documentary evidence of ownership rights. Because it offers the possibility to store these different types of immutable educational information on blockchain technology, blockchain technology is an important asset for education.

These different types of records can support education in different ways. First, blockchain technology in education can be considered a type or part of education technology. Education technology includes any technology that aims to facilitate learning (Januszewski & Molenda, 2008). The goal of such technology is to improve educational performance (e. g., online courses adapting to the learners' pace instead of face-to-face lectures; Januszewski & Molenda, 2008). Education technology offers new possibilities to deliver education and digitalizes education that was previously offline (c. f., Lusch & Nambisan, 2015). Being a type or part of education technology, blockchain technology supports learning and thus the core of education (e. g., by offering tokens to motivate learners). Second, blockchain technology can be used to support administrative functions in education, such as storing educational performance data (e. g., certificates). Through the possibility to store educational data, blockchain technology can, for example, connect learners to future employers. Third, blockchain technology can be used to protect intellectual property. In this case, the application of blockchain technology does not serve a strictly educational purpose. However, intellectual property is an important component of knowledge creation and thus of educational institutions.

The amplitude of the role of blockchain technology can vary. On the one hand, blockchain technology can serve as a component of education technology. This means that the education technology has a distinct main function (e. g., an online course) and blockchain technology supports part of this main function (e. g., offering tokens for learners within the online course). On the other hand, blockchain technology can be the main part of the education technology. For example, the blockchain may store the educational record of a learner. In this case, blockchain technology enables the creation of entirely new types of education technology.

In general, blockchain technology provides some key advantages for education compared to data stored in the usual way. Based on their analysis of the blockchain literature, Grech and Camilleri (2017) identify, for example, the following advantages: self-sovereignty (i. e., learners have control over their own performance record) and identity (i. e., being able to be identified online), trust (i. e., blockchain technology provides trust through its architecture as a decentralized ledger), immutability (i. e., the decentralized network on which the blockchain is based prevents the corruption of data by outside entities), and disintermediation (i. e., blockchain technology can replace middlemen such as education institutions) (Swan, 2017; Underwood, 2016; Yli-Huumo et al., 2016). We further assume that efficiency (e. g., through cutting out intermediaries), equal opportunities (e. g., censorship is not possible, and socially disadvantaged learners receive similar opportunities) and motivation (through tokens) are the main advantages that blockchain technology offers for education. These advantages are linked to each other and have their roots in the architecture of blockchain technology as a decentralized digital database.

However, all blockchain-based education technologies do not necessarily offer these advantages equally (Underwood, 2016). For example, a platform that saves educational data focuses on trust between learners and future employers, whereas a learning platform that hands out blockchain-based tokens to learners has a particular focus on enhancing learners' motivation. Through these advantages, blockchain technology might enable education technology to provide service solutions that education currently needs. Education is based on a "one-size-fits-all" principle, and blockchain-based education technology might allow more individualization. The changes induced by blockchain technology range from simple digitalization of current education to the disruption of education and therefore the provision of entirely new service solutions.

Blockchain-based education technologies might also be useful for employers, who can gain trust in applicants through the use of blockchain technology (e.g., certificates saved on blockchain technology). To understand blockchain-based education technology, it is necessary to distinguish among the main parties involved in blockchain technology (i.e., who is the main addressee of a particular technology, and who else might be involved in using it) (c.f., Kuvshinov et al., 2018). Blockchain-based education technology can focus on learners, educators or future employers (e.g., reducing degree fraud) (Chen et al., 2018). In addition, blockchain-based education technologies might facilitate learning for particular educational institutions (e.g., pre-school or university level).

3 Method

Table 1 provides an overview of the research procedure, which will be specified in the following sections according to these two steps.

Table 1: Research process.

Sample construction
– Database search
– Filtering of sample
– General search (white papers, etc.)
Qualitative content analysis followed by quantitative analysis
– Development of variables based on theory
– Adaptation of variables
– Data collection
– Descriptive analysis of results

3.1 Sample construction

We based the study on the analysis of the blockchain technologies themselves. The goal was to gain a deep understanding of the blockchain-based education technologies and their advantages and characteristics, which might allow them to induce change in education. To develop a full list of blockchain-based education technologies, we relied on the Crunchbase and Venture Radar databases to retrieve firms offering such technologies. Additionally, because some blockchain-based education technologies are currently being developed and therefore may not yet be included in official databases, we used Google to find newspaper articles and/or white papers, and we used provider websites to identify additional providers to include in our list. We retrieved 36 providers from Crunchbase. We used the search terms "blockchain" and "decentralized" in combination with eleven different search terms (namely, education, edtech, e-learning, intellectual property, document management, identity management, record, licensing, grant, recruitment, certificates) in the categories and descriptions of the providers. We retrieved possible search terms from Grech and Camilleri's (2017) analysis of the possibilities for using blockchain in education. In Venture Radar, we used the general term "blockchain" in combination with "education"; however, we did not identify any additional providers compared to those we retrieved from Crunchbase.

As the goal of this study is to assess providers that use blockchain for educational purposes (i. e., learning, administration or any support for learners in general), we filtered the list according to this definition and excluded providers that were not based on blockchain technology or had no educational purpose; we also excluded duplicates. This procedure resulted in 36 providers.

Subsequently, we systematized the Google search by using the search term "blockchain" in combination with "firm", "company" and "startup" and the eleven search terms we used in Crunchbase (see above). This procedure resulted in additional 26 providers. We screened the providers according to how well they fit our definition. Our final sample size is 62.

The 62 providers in our sample were from 25 countries. Most providers came from the United States ($N = 22$; 35.5 %) and from Europe ($N = 22$; 35.5 %), while 10 came from Asia (16.1 %) and 2 from South America (3.2 %; $N_{missing} = 6$, 9.7 %). Most providers had between 1 and 10 ($N = 22$; 35.5 % %) or between 11 and 50 ($N = 30$; 48.4 %) employees ($N_{other} = 3$, 4.8 %; $N_{missing} = 7$, 11.3 %). One provider was founded in 1980. The rest of the providers were founded between 2012 and 2018 ($M = 2015.49$; $SD = 4.83$; $N_{missing} = 1$, 1.6 %). A total of 12.9 % of the providers were financed through investors ($N = 8$), 19.4 % through initial coin offerings (i. e., crowdfunding through token sales/cryptocurrency, $N = 12$), and 4.8 % through both investors and initial coin offerings ($N = 3$). Information on funding type was not available for 62.9 % of the providers

(N = 39), partly because the providers were still in a testing/beta phase (N_{beta} = 16, 25.8 %; $N_{alpha/testing}$ = 9; 14.5 %) and not yet fully operating ($N_{Operating}$ = 30, 48.4 %; $N_{missing}$ = 7; 11.3 %), and partly because it is difficult to retrieve this information for small providers. As a result, our sample includes fully operating firms as well as blockchain-based education technologies currently in development. A total of 58.1 % of the education technologies were based on Ethereum (N = 36), 3.2 % on Bitcoin (N = 2), 9.7 % on EOS (N = 6), and 1.6 % on NEM (N = 1); 1.6 % used a private blockchain (N = 1), 4.8 % could be used on more than one blockchain (N = 3) and 6.5 % used other blockchain technologies (N = 4; $N_{missing}$ = 9, 14.5 %).

3.2 Qualitative content analysis followed by quantitative analysis

We chose a qualitative content analysis followed by a descriptive analysis of the results. By choosing this method, we aimed to filter out the most important characteristics and advantages of blockchain-based education technologies. The websites of the blockchain-based education technology providers were chosen as a source of information, as they describe the benefits and characteristics of the relative technology. Thus, this source of information was chosen as a means to retrieve a number of comparable and quantifiable variables.

We developed the variables using the following procedure: One part of the variables was based on current knowledge about blockchain technology in general and blockchain-based education technologies in particular. We added other variables due to the current context of education. The initial coding scheme was developed by the first author of this paper. Table 2 summarizes all variables, categories, and the origin of the variables.

During the coding of the providers, we added additional categories, but we also condensed highly similar or not distinguishable categories. We revised the categories four times based on the first 30 blockchain-based education technologies. In order to facilitate the coding, each variable was defined and categories were specified using a detailed description of their meaning and examples. [For a deeper understanding of the meaning of the variables, see the theory section.]

Information about the variables was retrieved from several sources: the websites describing the blockchain-based technologies, available white papers, Crunchbase and LinkedIn pages. It took between 20 minutes and 1 hour to assess the information for each blockchain-based education technology. One rater coded the variables, and a second rater verified the codings. Critical cases were discussed between the raters, and a joint decision was made.

4 Results

The results of the descriptive analysis are presented in Table 2.

Table 2: Description of codings and results.

Variable **Reference and definition** **Mean (SD) of number of codings**[a] **Categories**	**% (k)**
Main function of blockchain technology Grech and Camilleri (2017); i.e., what is the blockchain technology used for?; 3 (1.30)	
Formal and non-formal achievements	21 (37)
Intellectual property management	5 (8)
Currency: payments to institution	16 (28)
Currency: payments to learner	12 (21)
Rewards/payment for content creators	20 (35)
Student identity	1 (2)
Smart contracts	25 (44)
Main function of the education technology (self-developed); based on the descriptions of the education technologies, i.e., not always the same as the functionality of the blockchain technology; 1.65 (0.93)	
The education technology does not go beyond the function of the blockchain technology	20(20)
Learning platform (several courses)	24 (24)
Knowledge platform	2 (2)
Collaborative/peer-to-peer learning platform	13 (13)
Application platform for a particular institution	1 (1)
Game-based learning	6 (6)
Entire learning institution, e.g., a university	2 (2)
Social/professional network	10 (10)
Match/connect tutors and learners	1 (1)
Match/connect employer to candidates	20 (20)
Others	3 (3)
Type of records saved Grech and Camilleri (2017); 2.24 (0.84)	
Transactions of currency	33 (46)
Documentary evidence of ownership rights	6 (8)
Smart contracts	32 (45)
Digital signatures and certificates	29 (40)

To be continued

Table 2, continued

Variable Reference and definition Mean (SD) of number of codings[a]	
Categories	**% (k)**
Key advantages of blockchain technology Grech and Camilleri (2017); i.e., significant possibilities offered by blockchain technology that go beyond the possibilities currently available; 2.69 (1.11)	
Self-sovereignty and identity	8 (13)
Trust	24 (39)
Immutability	17 (27)
Disintermediation	13 (21)
Efficiency	17 (28)
Equal opportunities	7 (12)
Motivation	15 (24)
Does the technology help to individualize education? (self-developed); i.e., can learners receive individual education through blockchain technology instead of "one-size-fits-all" education?	
Not at all	77 (48)
Some individualization	16 (10)
Entirely individualized	7 (4)
Does the technology help to provide for the needs of future employers? (self-developed); 1.37 (0.61)	
Not at all	31 (26)
Provides more trust	34 (29)
Employees gain more knowledge	8 (7)
Finding more suitable candidates and/or finding candidates faster	27 (23)
Who is the addressee? (self-developed); i.e., who uses the technology?; 1.65 (0.68)	
Learners (i.e., members of a learning institution)	11 (14)
Teachers/instructors (i.e., for their own education)	2 (2)
General public (i.e., users who do not belong to an institution)	41 (52)
Institutions (i.e., for their own content)	10 (12)
Job seekers	28 (35)
Researchers	10 (12)
Who is the second user? (self-developed); i.e., who, besides the addressee, additionally provides something by using the technology or profits from the technology (e.g., addressee saves certificates, and an employer can verify them)?; 1.19 (0.46)	
Students (i.e., can serve as tutors)	1 (1)
Teachers/instructors	20 (15)
Institutions	4 (3)

To be continued

Table 2, continued

Variable Reference and definition Mean (SD) of number of codings[a]	
Categories	**% (k)**
Employers	39 (29)
Others	5 (4)
No second user	30 (22)
Target group (self-developed); i.e., if the technology has a direct learning function (e.g., learning platform), for which group of learners is the technology made?; 1.37 (0.70)	
Kindergarten or preschool	4 (3)
School	9 (8)
Higher education or college	18 (15)
Adults	25 (21)
Companies in particular	4 (3)
No direct learning function	41 (35)

[a] If several categories were applicable, the variables were assigned several categories. This was the case for all variables except for "Does the technology help to individualize education?". For these variables, the number (k) of codings and the percentage of codings therefore describe the absolute percentage of codings.

4.1 General function of blockchain technology and education technology

Very often, a blockchain technology serves as a means of recording formal and non-formal achievements (e.g., verifiable digital educational records), as a reward or payment for content creators (e.g., offering tokens to instructors involved in an online learning platform), and to produce smart contracts regulating demands and achievements (e.g., assignment and storage of certificates for successful completion of courses on the blockchain).

In 20 % of cases, the main function of the education technology did not go beyond the main function of the blockchain technology (e.g., the education technology offers instant issuance and authentication of digital records, which is congruent with the main function of the blockchain technology). An example is the technology Learning Machine which represents a credentialing system to issue records. The main function of this technology is entirely based on blockchain-technology. However, in the other cases, there was a difference between the underlying function of the blockchain technology and the function of the education technology.

In the largest proportion of the cases, blockchain technologies were used within learning platforms (e.g., an online learning platform using blockchain technology to provide learners with tokens and certificates), to match/connect employers to candidates (e.g., a platform to connect candidates and employers and to allow employers to access candidates' verified resume information through blockchain technology), within collaborative/peer-to-peer learning platforms (e.g., a peer-to-peer online learning platform using smart contracts to connect the learning community) and within social/professional networks (e.g., a professional network using blockchain technology to validate skills and to enable users to continue to master their data). The types of record saved on the blockchain were often transactions of currency, smart contracts and digital signatures and certificates (mostly saved as hashes).

4.2 Use of blockchain technology for education and employers

All blockchain-based education technologies demonstrated the advantages of blockchain technology that have been discussed in the literature. Most blockchain-based education technologies aimed to provide trust, followed by immutability. An example is Everipedia, which uses blockchain technology to democratize and decentralize an online encyclopaedia. Besides, during the assessment of the technologies, we added the categories efficiency (e.g., faster solutions through automatized reward systems) as well as equal opportunities and motivation (e.g., the use of cryptocurrencies (i.e., tokens) to motivate learners to participate), which were also often provided by the education technologies (i.e., equal opportunities were less common than efficiency and motivation). An example of a blockchain-based education technology that provides equal opportunities is an online, publicly editable, free encyclopaedia that disenables censorship by governments. Overall, the blockchain-based education technologies showed an average of 2.69 (SD = 1.11) advantages.

Most of the blockchain-based education technologies in our sample did not pursue the goal of individualizing education; only a small portion of the technologies made this their aim. However, it is important to recognize that most of the individualization of education is caused by the education technology (e.g., through live video chats) and not by the blockchain technology. For example, the micro-learning platform Code of Talent, which is blockchain-based, plans to provide a variety of different courses paired with interactions.

The needs of employers, however, can be addressed through blockchain-based education technologies in more than half of the cases. Employers can profit from the trust created through blockchain technology. In addition, the technology enabled them to find more suitable candidates and/or to find candidates more quickly.

4.3 Target group of blockchain-based education technologies

Most of the blockchain-based education technologies were made for the general public and therefore for learners who were not particularly associated with one institution (e.g., learning platforms with no particular target group) or for job seekers (e.g., connecting job seekers to employers).

Almost 30 % of the technologies did not have a second user giving input or profiting from the technology (e.g., when tutors and learners are connected through a learning platform, there is a second user; but there is no second user when a learner simply uses the platform to store his/her certificates). Among those technologies that did have a second user, most were used by employers, followed by teachers/instructors (e.g., a skill-sharing platform connecting knowledgeable instructors with learners).

Over 40 % of the blockchain-based education technologies did not have a direct learning function but rather had an administrative or supportive function. Of the technologies with a learning purpose, most were developed for higher education and/or adults in general.

5 Discussion

This study is the first to systematically analyse the use of blockchain technology in education. We assess the blockchain-based education technologies that are currently or will soon be available for innovation in education. Based on our analysis, we develop an agenda for future research.

We analysed 62 providers that apply blockchain technology in different ways for an educational purpose. The blockchain-based education technologies analysed here include some technologies that have a learning focus and others that perform administrative and supportive functions in education. In line with the previous literature, our content analysis reveals that blockchain-based education technologies offer many advantages for education. For example, they are efficient, have a motivational purpose and enable equal opportunities for learners. More than half of the technologies were useful for employers, but only some contribute to the individualization of education (i.e., mainly through additional functions of the education technology and not through the functionality of the blockchain technology). Current blockchain-based education technologies were primarily made for the general public and job seekers, and the ones with a learning function mainly target adult learners and higher education. However, these are only general tendencies, as the set of blockchain-based education technologies analysed here is quite diverse.

5.1 Contribution to answering the question of whether blockchain-based education technologies can disrupt education

We contribute to a highly relevant research topic by analysing how blockchain technology can be applied to education. Our results provide a deeper understanding of blockchain technology in education and serve as a signal to educational stakeholders by highlighting the importance of blockchain technology in education. Particularly, returning to the question of whether blockchain-based education technologies have the potential to disrupt education, we can conclude the following based on our results.

We find that a large portion of the education technologies serve a wider purpose than the underlying blockchain technology itself. This finding underlines the compatibility of blockchain technologies with current education technologies. Through its unique features, blockchain technology seems to have the capacity to improve education technologies. However, the fact that blockchain technologies are only used to individualize education in some cases also indicates that blockchain technology might need further development to contribute to the disruption of education. The results show that the types of records saved on blockchain technology are approximately equally distributed (except for documentary evidence of ownership rights), showing that all current possibilities for saving records on the blockchain are being used.

Blockchain-based education technologies seem particularly promising because they provide many advantages compared to traditional education. Among other advantages, blockchain technology serves as a disruptor of traditional education through its purpose of building trust between the involved parties. In addition, we found that blockchain-based education technologies aim to enhance efficiency and motivation as well as to provide equal opportunities for learners. This finding further underlines how useful blockchain technology can be to enable a movement towards digitalization and social equality. Most blockchain technologies offer several advantages, highlighting the important changes that blockchain-based education technologies can create.

It is not surprising that most blockchain-based education technologies did not pursue the goal of individualizing education, as the particular structure of blockchain-based education technologies enables the creation of democratic opportunities. Employers seem to profit from blockchain-based education technologies. Particularly, technologies that provide more transparency regarding learners' achievements – and therefore their skillsets – can enable trust between employers and potential candidates and help the employers to find suitable candidates.

The finding that most blockchain-based education technologies address a general public or job seekers demonstrates the capacity of blockchain technologies to improve learning opportunities for all groups of learners. However, this finding also shows that higher education institutions should not miss the chance to take advantage of blockchain-based education technologies, because they provide learning opportunities that go beyond those offered by traditional education.

In summary, considering the question of whether blockchain technology has the potential to disrupt education, we can conclude that blockchain-based education technologies already offer many approaches to possibly changing education and therefore have the potential to provide substantial educational innovations. However, this process of change is currently only in its infancy.

5.2 Conclusions about blockchain-based education technology and future research

In this paper, we found that blockchain technology can be applied to education and provides important advantages for education. We focused specifically on blockchain-based education technologies. However, our analysis does not allow conclusions about the actual use of blockchain-based education technologies in education. According to recent newspaper articles, press releases and blog posts, higher education institutions and employers have started working with blockchain technology or are currently developing ideas about how to employ blockchain technologies in education (i. e., to award and save student records and to verify students' academic achievements) (Skiba, 2017). Examples are the Media Lab Learning initiative of the Massachusetts Institute of Technology and Sony (Friedlmaier et al., 2017; Rooksby, 2017; Russell, 2017; Turkanović, Hölbl, Košič, Heričko, & Kamišalić, 2018). However, most of these initiatives are currently under development, and the application of blockchain technology to education is clearly still at an early stage. One reason for this modest use of blockchain-based education technologies is that, even though research on blockchain technology is booming, it is also still in its infancy. Similarly, the creation of blockchain-based business models is a recent but up-and-coming area. Therefore, educational institutions might not yet be aware of the available blockchain-based education technologies and may not yet have the blockchain-based education technologies they need (i. e., some of the assessed blockchain-based technologies were still in a beta phase). Another reason for the rather modest adoption of blockchain-based education technologies is that education is a very particular context. Education – and particularly educational institutions – react slowly to digitalization in general and are managed very traditionally. As a result, it is interesting to become aware of their needs when it comes to the introduction of blockchain-based education technologies.

In a similar vein, we analyse the advantages of blockchain-technology for higher education and provide important information on the characteristics of these technologies. Our analysis offers a provider-oriented view of the advantages of blockchain-based education technologies. However, the perspectives of other important stakeholders remain open. For example, the acceptance and demands of potential users of blockchain-based education technologies are highly important when it comes to the introduction of such technologies. This perspective is important in order not only to get a perspective on the users' needs but also to understand which difficulties might arise while introducing the use of blockchain-based education technologies.

However, blockchain technology itself also requires further development. For example, researchers are currently working on the following topics: (1) problems in scalability (Swan, 2015), (2) speed versus security trade-offs (Kiayias & Panagiotakos, 2015), (3) decreasing the currently high costs of operating blockchain technology (e. g., hardware) (Zambrano et al., 2017) and (4) decreasing the use of the vast amounts of energy consumed by blockchain technology (Zambrano et al., 2017). These aspects also affect the usability of blockchain technology in education. In particular, even though blockchain technology might provide advantages for developing countries, its infrastructure requirements are still very high and might therefore create obstacles for emerging economies to participate in blockchain-based education (Zambrano et al., 2017).

In this paper, we addressed blockchain-based education technologies, concentrating on technologies with a focus on education. However, one clear advantage of blockchain technology is that it might be able to connect several industries and aspects of everyday life. For example, in this paper, we assessed blockchain-based education technologies in the area of identity management when there was a connection to education. However, identity management in general can be applied to many areas of everyday life. We did not include blockchain-based technologies with a general focus that might still be applicable to education but do not focus specifically on education.

Previous research has already pointed to the assumption that the changes that occur in various business areas through blockchain technologies might be rather gradual than instantaneous and disruptive (Iansiti & Lakhani, 2017; Swan, 2015). Our results seem to confirm this point of view.

Our findings and literature analysis leave us with the following questions for future research: First, research should continue to consider new ways to apply blockchain technology to education. For example, smart contracts might be used to regulate achievements (Zambrano et al., 2017), and knowledge platforms such as Everipedia could be further developed in the direction of peer-to-peer learning platforms. Therefore, the possibilities that blockchain technology provides with regard to the democratization of education should be explored. Swan (2015) assumes that the application of blockchain in areas such as education will take extra time. Future research should promote the development of blockchain-based education technologies. Second, as described above, blockchain technology must be further developed before it can fulfil the needs of education. Information systems research is in a unique position to focus on precisely this type of development. Third, blockchain-based education technologies should be tested in the context of education. Future studies should assess how blockchain technology can be integrated into other education technologies. Fourth, studies should assess the perspectives of other stakeholders on the introduction of blockchain-based education technologies (e.g., the conditions under which users accept blockchain-based education technologies). Fifth, future research should determine which blockchain-based education technologies educational institutions need as well as the requirements that must be met if education is to include blockchain-based education technologies in teaching (i.e., with regard to both policies and technological needs). Sixth, future research should assess business models of blockchain-based education technologies. For example, we found that many blockchain-based education technologies use cryptocurrencies to raise money instead of using a process of venture capital acquisition; this choice might be an interesting aspect of these new business models. Seventh, in this paper, we focused on the positive consequences of using blockchain technology in education. However, there might also be negative consequences. For example, with regard to a learner's curriculum vitae, until now, one could omit certain work experiences from their application in order to highlight their specific suitability for a position. Such changes might not be possible if blockchain technology is used. Hence, future research should take a holistic approach and analyse positive as well as negative consequences of the use of blockchain technologies in education. Future research should rely on different data sources, such as surveys or interviews, to consider users' perspectives on blockchain technology. Similarly, as soon as blockchain-based education technologies become more commonly used in education, objective user data could be used as a basis for analysis, for example, in relation to performance data.

6 Conclusion

In conclusion, we assume that blockchain technology can induce change in education. However, we feel confident that this change is not yet complete. Blockchain technology is in a constant process of development, and future research should continue to harness the possibilities blockchain technologies offer for education.

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